Physical Methods for the Decontamination of Meat

Introduction

Until recently, contamination of poultry, pork or beef carcasses by zoonotic pathogens and of the deboned and further processed fresh meat derived thereof has been one of the most challenging problems in food hygiene worldwide. From an epidemiological point of view, research and risk management approaches are aimed at reducing the prevalence as well as the bacterial load of Campylobacter, Salmonella, Yersinia enterocolitica, pathogenic Escherichia coli and Listeria monocytogenes, which have been the main cause of human foodborne infections in the EU, with over 350,000 reported cases in 2018. In recent decades, different strategies and measures have been applied, mainly at the pre-harvest level, but, except for in the case of Salmonella in poultry, with varying degrees of success. Therefore, recently developed strategies aim to include the entire processing chain, including transportation, stunning and slaughtering, deboning and further meat processing. In the case of Campylobacterin poultry, strategies should mainly be focused on post-harvest levels. In this context, the impact of physical, chemical and biological decontamination technologies has been the subject of a number of studies which have focussed on the potential use of chemical decontamination. Although a number of these appear to be promising alternatives, only a few can legally be applied during meat processing, e.g. the use of lactic acid for the decontamination of beef carcasses in the EU or the chlorination of poultry carcasses in various countries outside the EU. Physical methods, particularly dry interventions, are considered to be fast, mild and residue-free, and have received more attention.

1-Gamma Ray (γ-Ray) and Electron Beam (e-Beam) Irradiation

Food irradiation has already been applied for many decades and has been approved in around 60 countries around the world. The exposure of food to ionizing radiation, either in form of electromagnetic energy Gamma ray (γ-ray) or charged particles electron beam (e-beam) can improve the microbial safety of food and extend its shelf life, even resulting in the sterility of the product. Whilst the radioisotopes caesium-137 or cobalt-60 are used as source of γ-rays, e-beams are produced by a linear accelerator. Irradiation inactivates microorganisms directly by photoninduced single and double-stranded DNA breaks, and indirectly by DNA damage, which is induced by radiolysis products, e.g. hydroxyl radicals. The antimicrobial properties of both forms of irradiation are comparable, but e-beams allow a higher dose rate (e-beam 103 –105 Gy/s; γ-ray 0.01–1 Gy/s **The gray (symbol: Gy) is the unit of ionizing radiation dose in the International System of Units (SI), defined as the absorption of one joule of radiation**), resulting in a shorter application time. In contrast to ebeams, γ-rays penetrate deeper into the food matrix (60– 80 cm vs. 8–10 cm). Complex life forms, which contain large DNA molecules, are affected by relatively low doses of less than 0.1 kGy, whilst simple life forms with smaller DNA such as bacteria (1.5–4.5 kGy) or spores (10–45 kGy) are inactivated at higher doses. In general, gram-negative bacteria are more sensitive to irradiation than gram-positive bacteria, but serotype and serovar variations have also been documented for E. coli and Salmonella, respectively. Besides bacterial species, food composition (primarily water content), thickness and temperature also have an effect on irradiation efficiency. Frozen or dry foods need higher doses of γ-ray or e-beam, because low product temperatures reduce the diffusion of free radicals.

2- Pulsed Light

Pulsed light (PL) treatment, inter alia, pulsed UV-light (PUV), intense pulsed light (IPL) or HIPL (high-intensity pulsed light) is characterized as another rapid and gentle decontamination technology. Inert gas flash lamps (mostly xenonbased) are used to generate very short (μs) high power pulses of broad-spectrum light. PL has a similar spectrum to sunlight with wavelengths from 200 to 1100 nm and encompasses ultraviolet (UV), visible (VIS) and infrared (IR) light, with an enormous output in the UV range. Flashes of light have a higher decontamination efficiency than the continuous application of UV-light because the energy incorporated is multiplied manifold. The inactivation of microorganisms is a nonselective multitarget process, in which the photo-chemical effect is the most important mechanism. UV-C light is absorbed by DNA and pyrimidine dimers are formed, hindering DNA replication. The IR light component has a photo-thermal effect at higher powers, at which local overheating results in cell damage and cell ruptures. shape and cell membrane, cytoplasmic damage and the leakage of intracellular compounds. The majority of publications reported a higher resistance of gram-positive bacteria in comparison to gram-negative bacteria] but strain-dependent susceptibility has also been observed. The inactivation of fungal and bacterial spores differs and depends on the presence of pigments

3-Ultraviolet (UV-C) Light

UV-C (200–280 nm), a type of the ultraviolet light (100– 400 nm), can help sterilize liquids, indoor air or surfaces. Unfortunately, it is still underused in the food industry. The major goal of all studies has been to reduce pathogenic microorganisms in food products and extend shelf life without impairing freshness. UV-C light generates photoproducts during treatment (pyrimidine pyrimidone (6– 4) and pyrimidine dimers) resulting in damage to microbial DNA and proteins in living cells. DNA damage may involve the crosslinking of the strong hydrogen bonds between the nucleobases thymine–cytosine. DNA-transcription and replication are thus disturbed, which can disable repair processes, and cause mutations and cell death. In relation to raw meat decontamination, several research groups have examined the potential of (**UV-C LEDs** **What is a UV-C LED? Light-emitting diodes (LEDs) are semiconductor devices that are made up of multiple layers of substrate materials. They can be designed so that a wavelength can be inputted and emit photons in the UV-C range that can be used to stop the replication of bacteria)** for the reduction of microbial load. For example, with doses of up to 2040 mJ/cm2 , 0.56, 0.82 and 0.95 log reductions were achieved for Yersinia enterocolitica on pork after 1, 7 and 14 days of storage), respectively. Similar results were reported at 1 J/cm2 (1000 mJ/ cm2) UV-C for Yersinia pestis on chicken breast filets and beef steaks. In another study, greater reductions of up to 2.4, 1.8, 2.6 and 1.7 log were obtained for Salmonella Enteritidis, Listeria monocytogenes, Staphylococcus aureus and enterohaemorrhagic Escherichia coli, respectively, when chicken filets were irradiated with doses of up to 3 J/cm2 at a distance of 6 cm

4- Cold Atmospheric Plasma

Non-thermal atmospheric plasma or cold plasma is another of many emerging food preservation technologies which can effectively reduce food-borne pathogens with only minimal detectable effects on product quality, or with none at all. In general, cold plasma consists of UV photons, excited atoms and molecules, electrons, ions, free radicals and reactive species (atomic oxygen, hydroxyl radicals, ozone, nitrogen oxides, singlet oxygen and superoxide), which have the ability to kill bacteria, viruses and fungi. These compounds cause cell misfunction through the lesions in the membrane, the breaking of chemical bonds in the cell wall, intracellular disorder, loss of enzyme activity, denaturation of proteins and damage to RNA and DNA, which can lead to bacterial cell death. Since 2015, several studies have significantly increased knowledge of cold plasma and its applications in the food industry.

5-High Pressure

High pressure processing (HPP) is a non-thermal, residuefree technology and has been applied in the food industry for several decades. For application, the food is vacuumpackaged in a flexible and water-proof package and submitted to a pressure vessel to pressures generally ranging from 100 to 600 MPa, depending on the product. This takes a few minutes and is carried out at ambient temperatures. In contrast to most other technologies, HPP treats the whole product, as the isostatic pressure affects the food product virtually instantaneously and uniformly, regardless of geometry and size. Small molecules, such as vitamins and flavour compounds are unaffected, which is relevant to the taste and nutritional value of the product. HPP affects noncovalent bonds (electrostatic and hydrophobic interactions) therefore macromolecules such as proteins are subjected to changes in their tertiary and quaternary structures. Consequently, cell structures are disrupted by protein denaturation, lipid conformation and enzyme inactivation, which promote the inactivation of microorganisms. Bacteria are generally more resistant than yeast and moulds and, with some exceptions, gram-positive bacteria are more resistant than gram-negative bacteria. In addition, variations between strains in resistance to pressure have been demonstrated . in the case of Salmonella. Diverse studies have shown the efficiency of HPP in the reduction of pathogenic bacteria in raw poultry, beef and pork meat and organs.

6- Ultrasound

Ultrasound treatment or ultrasonication (US) is an emerging technology for diverse applications in food and nonfood areas which has been known of for some time. Ultrasound is defined as sound waves with frequencies higher than the upper limit of human hearing (20 kHz) and is therefore distinct from audible and infrasonic waves. In detail, US can be divided into power ultrasound (16– 100 kHz), high-frequency ultrasound (100 kHz-1 MHz) and diagnostic ultrasound (1–10 MHz). US is already used in a variety of applications, e.g. measuring distances, cleaning, for sonography in medical imaging and in wastewater treatment. In food processing, it is used for the purposes of extraction, cleaning, emulsification and homogenisation. Because US is acoustic energy, ionizing and invasive effects can be excluded from consideration. Moreover, this technology uses a non-polluting form of mechanical energy and is therefore considered an emerging method for food processing which does not interfere with food quality, and which has high consumer acceptance. Under exposure to US, compression and rarefaction are induced in the molecules of the medium in question.